than to add. A problem to determine must be what shall be considered as fishes really belonging to the fauna. Certainly inhabitants of the deep seas, which never approach the territorial limits of a state, can not properly be considered as members of the fauna. Such types as the chimærids, simenchelyids, nemichthyids, saccopharyngids, alepocephalids and macruids are characteristic constituents of the deep-sea or bassalian realm. The involuntary estrays from tropical seas, whose lives are terminated with the increasing cold of the fall and winter months, also cannot claim to be reckoned as constituents of the fauna. They are representative of a very distinct realm—the Tropicalian. They do, however, furnish very useful hints for the determination of zoogeographical problems. We have the evidence that in times past a few estrays from tropical families have established homes far from those of their kindred. All such problems and considerations, however, must now be left for the future and for other hands.

Theo. Gill.

Smithsonian Institution.

THE COLD-CURRENT SYSTEM OF THE PACIFIC, AND SOURCE OF THE PACIFIC COAST CURRENT.

I propose to offer reasons for believing that an immense system of currents of ice-cold water occupies a large part of the Pacific Ocean, corresponding in magnitude to the vast warm-current system of the equatorial Pacific, which culminates in the great Gulf Stream of Japan, or the Kuro Siwo.

But preliminary to this I would note some points relative to that remarkable stream of cold water, which flows in a vast volume southerly, skirting southeast Alaska, Vancouver's Island, the Pacific states of Washington, Oregon and California, and finally passes out westward to Hawaii, beyond which group it becomes merged into the great equatorial current running westward.

This stream is of very low temperature, of immense volume and of great velocity. It is unique in its powerful effects upon the climates of the coasts along which it flows. To the states of Washington and Oregon throughout the summer it imparts a constantly cool and moist climate extending over one hundred miles into the interior. It also greatly mitigates the cold of winter. Both these conditions are in strong contrast to the arid summer and biting winter climates which prevail in the interior of those states east of the Cascade Range.

To the entire coast of California from Klamath to Los Angeles this current lends chill fogs throughout the summer afternoons, whose moisture clothes with verdure the coast hills for many miles in breadth, while the interior of the state is dry and parched. It makes warm clothing needful in San Francisco every day in the year. It also mitigates the scorching heats of the interior valleys of California, giving cool nights to render them habitable.

Finally turning westward like the trade winds under the impulse of the globe's rotation, this mighty current broadens out into the open ocean, gradually gaining warmth. After traversing 2,200 miles it reaches the Hawaiian Islands, still at the low temperature of 70° in late summer, and of below 60° in late winter. This imparts to that favored group a uniformly subtropical climate such as is unknown to any other land in the same latitude. Borne on this powerful current there may often be seen passing the islands or landing on their shores, immense trees as well as saw-logs which have been swept to sea by freshets in the Columbia River.

What is the source of this mighty current? This is a problem not hitherto solved. It has been the custom to call it a

continuation of the great Gulf Stream of Japan or Kuro Siwo. To that solution of the problem there are two objections which appear insuperable.

One is that the Japan stream must necessarily pass out and dissipate itself in the vast breadth of the Pacific Ocean long before reaching Alaska. Even if enough of the Kuro Siwo could hold together to form a noticeable current on the Alaskan coast, it could be only a wasted and meager stream, wholly unlike the mighty current that skirts the continent.

The other objection is the extreme coldness of the American coast-current. This could not possibly proceed from water of such high temperature as the Kuro Siwo, if the latter had held together as a compact stream. So compacted, it must have retained most of its warmth, even in traversing the higher latitudes. It has been alleged that it has been chilled by passing the vicinity of the great Alaskan glaciers. But the Muir glacier, the Malaspina and all combined are of comparatively limited extent. They send no bergs out to sea; they are totally inadequate materially to cool the adjacent ocean.

What then is the real source of the Pacific coast cold current? Leaving for a little this problem, turn we now to a second one, which may help us to find the answer to the first. The depths of the Pacific Ocean are occupied throughout by an immense stratum of ice-cold water at 35°, which is slowly creeping northward. The existence of this cold stratum is well established by all deep-sea temperature soundings throughout the Pacific. That it is creeping northward is inferred from an analogous condition under the Atlantic Ocean. It is a fact familiar to hydrographers that a similar stratum of cold water underlies the Atlantic at a depth of 2,000 fathoms. Near the equator, however, the 35° stratum is found to rise to within a few hundred fathoms of the surface. The necessary inference is that two opposite currents are meeting and pushing each other upwards, the one derived from the Arctic ice, the other from the Antarctic. Nearing the surface they gather warmth and commingle with the warm equatorial current running westward.

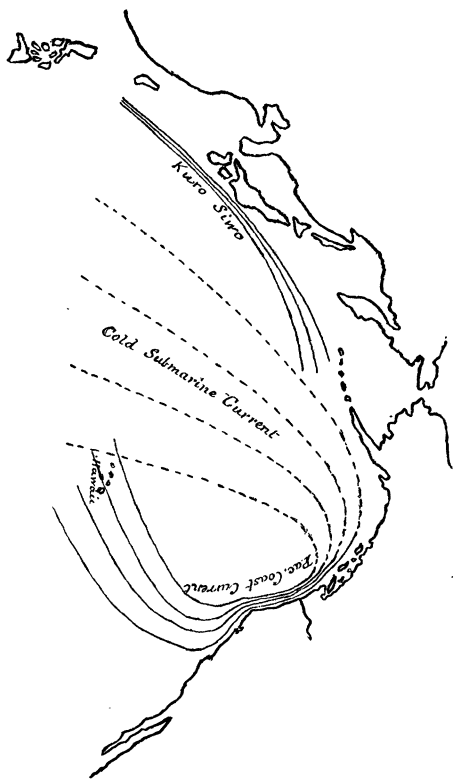
But in the Pacific Ocean, while the depths are at the same 35° as in the Atlantic, there is no rising of the cold water at the equator. The reason is evident. The supply of cold is confined wholly to the Antarctic ice. The Pacific is closed at the north, and the Arctic ice exerts no influence on its waters. There is no northern deep-sea current to meet and push up the southern one at the equator, and the latter creeps on unobstructed to the northern bound of the ocean.

This southern current is evidently of great magnitude. It proceeds from a Pacific frontage of the vast Antarctic continental glacier extending 4,000 miles in length along the Antarctic Circle. The ocean waters from the north encountering this massive ice-front and its bergs are chilled and sink to the bottom. Thence they creep north in a wide and deep stratum underlying the whole breadth of the Pacific. Reinforced and pushed on by constantly chilled supplies behind, they press on up the whole 8,000 miles' length of the ocean, encountering no adverse current from the Arctic Circle.

Here comes our second problem. Where does this vast creep of cold water find outlet? Somewhere it must escape to the surface. Where does it emerge to unite with the upper ocean? Before indicating the answer to this second problem, we may note two conditions encountered by this vast creep of water, which may assist in guiding us to the answer.

The first condition is that after passing the Tropic of Cancer, the Pacific Ocean

rapidly contracts in breadth. In latitude 45°, it is only half as wide as at the equator. The consequence is that the northward-moving waters are accelerated to twice their previous velocity.



The second condition is that in reaching a higher latitude this accelerated current becomes subjected to a powerful eastward thrust from the rotation of the globe. As its distance from the earth's axis diminishes in going north, its retention of the more rapid eastward rotation acquired at the southward must drive this current with great force to the east. The inevitable result must be that the whole body of cold water going north is driven powerfully against the shores of the North American continent in the latitudes of Sitka and Vancouver's Island. This is illustrated in the accompanying diagram.

Here then we have two problems, both relating to cold currents. The one concerns the source of the mighty Pacific coast current, the other relates to the final outflow of the deep-sea cold stratum. It is obvious that the two problems fit and solve each other. The answer to both becomes plain. The source of the coast current is in the deep-sea stratum. The outflow of the deep current is the great coast-current. Each fits the other. Together they constitute one system.

The deep-sea current driven by the globe's easterly thrust, and encountering the shoaling ocean bottom, is crowded against the coast, forced to the surface, and driven southwards as its only possible outlet. And so emerges to being the great Pacific coast current.

Such then is the story of the great Cold-current system of the Pacific. And such is the source of the wonderful cold current of our Pacific coast. It is generated by the massive continental glacier which skirts the Antarctic Circle. It slumbers long in the sluggish womb of the dark Pacific depths. It quickens to activity in the narrowing northern ocean. Finally stung to life by the rotary thrust of the globe, it springs to birth as the mighty current sweeping along the western shores of our continent, dispensing coolness and moisture to populous states. And finally it bestows coolness and calm and exemption from tempests to the islands, making a genial paradise of the otherwise sultry Hawaii. All those favored shores derive their genial climes from the transmitted coolness of the Antarctic ice.

I propound this as a most probable theory of a current system hitherto undivined. It remains to verify it by systematic soundings and determination of limits of the coast-current.

S. E. Bishop.

Honolulu, T. H.,
February, 1904.

NOTE.—Since the foregoing article was sent for publication, an important element is found to have been overlooked. This is the effect upon the coast current of the powerful westward thrust of globe-rotation, corresponding to that which causes the trade-winds and the equatorial currents. This thrust must begin to act with great power as soon as the coast current begins to move to the southward. Such thrust must absolutely forbid that great current to cling as it does to the coast from Alaska to southern California, unless some other force intervenes. This fact, therefore, constitutes an *absolute proof* that the source of the Pacific coast current is not from the Kuro Siwo, because as soon as that current should turn southward, it must at once be pushed by the globe rotation westward into the open ocean.

But this element of force proves much more. The fact that the coast current does actually move eastward of south, clinging to the eastward trend of the coast in opposition to the westward thrust to which it is subjected, demonstrates the presence all along its course of a very mighty source of eastward pressure. That source can be no other than the broad and massive current from the Antarctic pushing up from the deep sea under the easterly globe-thrust along the entire coast from Alaska to Los Angeles. As soon as that confining pressure is removed, the coast current turns westward, finally to unite with the equatorial current in the tropics.

I seem, therefore, to have the right to claim an absolute certainty for the theory that a cold current from the deep sea impinges against the American Pacific coast from Alaska to southern California. The vast body of cold water actually appearing there can by no possibility have moved from a northern source to the *eastward* of south, such direction being forbidden by the rotation of the globe. S. E. BISHOP.

MEMBERSHIP IN THE AMERICAN ASSOCIATION.

THE following persons have completed membership in the association since April 1, 1904:

Altamirano, Dr. Fernando, Instituto Medico Nacional, Esquina de Balderas y Ayuntamiento num 1202, Mexico, D. F. (53.) G.

Angle, Dr. Edward H., 1023 North Grand Ave., St. Louis, Mo. (53.) F.

Beck, Herbert H., Assistant Professor of Chemistry, Franklin and Marshall College, Y. M. C. A. Building, Lancaster, Pa. (53.) C.

Brown, Ernest William, ScD., Professor of Mathematics, Haverford College, Haverford, Pa. (53.) A, B.

Burkett, Charles William, Ph.D., Professor of Agriculture, N. C. College of Agriculture and Mechanic Arts, West Raleigh, N. C. (53.) C.

Cheever, Clarence A., M.D., 1531 Blue Hill Ave., Boston, Mass. (53.) G.

Chittenden, J. Brace, Department of Pure Mathematics, Brooklyn Polytechnic Institute, Brooklyn, N. Y. (53.) A.

Covert, Rev. William Ross, McMechen, West Virginia. (53.)

Eckart, Charles F., Director of the Sugar Experiment Station, Box 180, Honolulu, H. T. (53.)

Fisch, Dr. Carl, 3212 Pine St., St. Louis, Mo. (53.) K.

Frazer, T. H., M.D., Professor of Physiology, Dermatology and Hygiene, Medical Department, University of Alabama, Mobile, Ala. (53.) K.

Griffith, L. A., M.D., Upper Marlboro, Md.

Hauxhurst, Robert, Jr., C.E., Chief Engineer Kohala and Hilo Ry., Hilo, Territory of Hawaii. (53.) D.

Jeffrey, Robert Henry, Apartado 104, Oaxaca, Mexico. (53.) G.

Jennings, Otto Emery, 3233 Fifth Ave., Pittsburg, Pa. (53.) G.

Koch, Waldemar, Ph.D., Assistant Professor of Physiological Chemistry and Pharmacology, University of Missouri, Columbia, Mo. (53.) C.

Kribs, Herbert Guy, 300 Highland Ave., Chestnut Hill, Philadelphia, Pa. (53.) F.

Longaker, Daniel, M.D., 645 N. 8th St., Philadelphia, Pa. (53.) K.

McAdam, John Vaughan, Engineer, American Steel Foundries, 74 Broadway, New York, N. Y. (53.) D.

McMurry, Fred. R., Garden City, Kansas. (53.)

Michigan State Normal College, Ypsilanti, Mich. (53.)